6. (Amended Twice) A spring surface treatment method according to claim 3 or 4, wherein the particles used to bombard the spring surface and the projection conditions of the particles are limited to the following:

hardness of projected particles: initial hardness being Hv 350 to 1100;

size of projected particles: initial mean diameter of each particle being 10 μm to 80 μm;

mean diameter of all particles: 65 μm or less;

specific gravity of projected particles: 7.0 to 9.0; and

collision velocity against spring: 60 m/sec. to 140 m/sec.

REMARKS

Claims 1-15 are pending.

The amendment to claims 1-6 is cosmetic, e.g. in order to provide proper antecedent basis. Applicants submit that the amendment would not narrow the scope of the amended claim recitations.

Lack of Unity of Invention

Applicants' traversal of the lack of unity of invention holding was not found persuasive because the Examiner asserted that claim 1 was obvious in view of cited references of record. Applicants respectfully disagree that claim 1 was obvious in view of the prior art of record as discussed below. Accordingly, applicants respectfully request that claims 8-13 be rejoined with claims 1-7, 14 and 15 in the examination on the merits because the special technical features linking the examined claims and non-

elected claims did provide a contribution over the prior art and a single inventive concept existed.

Claim Rejections under 35 USC §112, first paragraph

Claim 15 was rejected as containing subject matter which was not described in the specification. Applicants respectfully traverse the rejection.

The Examiner's position was that the specification provided no support for the expression "mean diameter of all particles of 65 μm or less" in claim 15. Applicants note that the expression "mean diameter of all particles of 65 μm or less" was disclosed in claim 2 (line 6) as filed. Thus, there was descriptive support for the expression "mean diameter of all particles of 65 μm or less" in claim 15. Withdrawal of the rejection is requested.

Claim Rejections under 35 USC §112, second paragraph

Claims 1-2, 5, 6, 14 and 15 were rejected for indefiniteness. Applicants respectfully traverse the rejection.

Claims 1 and 2 were rejected because "the iron matrix" lacks a proper antecedent basis. Claims 1 and 2 have been amended to provide antecedent basis.

In claim 1, "step (c)" has been replaced with "step (C)" to be consistent with steps (A) and (B).

Claims 5 and 6 were rejected because the recitations "a mean diameter of all particles of 80 μm or less" and "mean diameter of all particles: 65 μm or less" were

inconsistent. Applicants submit that the amendment to claims 5 and 6 has removed the indefiniteness.

Withdrawal of the indefiniteness rejection is requested.

Claim Rejections under 35 U.S.C §103

Claims 1-7, 14 and 15 were rejected as obvious over JP 07214216 (hereinafter JP '216) or Izawa et al. (U.S. Patent No. 5,665,179) in view of Yamada et al. (U.S. Patent No. 5,816,088) and further in view of JP 08053711 (hereinafter JP '711). Applicants respectfully traverse the rejections.

The Examiner was not persuaded by applicants' argument that Izawa et al. uses shots bigger than the claimed methods because the Examiner took a position that a person skilled in the art knew that changing the diameter of the shots used will affect the result of the shot peening treatment. Applicants submit that, based on what was known in the prior art about the effect of changing the size of the shots used in shot peening, there would not have been any motivation of modifying the method of Izawa et al by replacing the shots used by Izawa et al with smaller shots (shots as small as the shots used in the claimed method) in shot peening. A person of ordinary skill in the art would have known that residual stress is obtained as a result of plastic deformation. The portion of nitrided springs at the surface (and even the portion near the surface) has been known to be very hard and not easily deformed plastically by shot peening because the very hard portion has very high yield stress. The person would have known that, in order to create plastic deformation in nitrided surface layer with high hardness, it is important to use shot particles of high kinetic energy in shot peening

treatments. Since the kinetic energy of a shot particle is proportional to the cube of the shot particle size (as the shot particle size is decreased, the kinetic energy is reduced tremendously), the person would have thought that large shot particles, such as of a size of 0.15 mm or 0.2 mm, are necessary for shot peening of the nitrided surface layer. The person would not have replaced the large shot particles with smaller shot particles. The person would have thought that the large shot particles, such as those of a size of 0.15 mm or 0.2 mm used by Izawa et al, can deform elastically the hardest surface thin layer and at the same time can strain plastically inner nitrided portion wherein it is not as hard as the surface layer but harder than the core of the nitrided spring, resulting in rather effective compressive residual stress formation in the surface layer of which maximum compressive stress is obtained not at its surface but in the portion just beneath the surface. The person would not have motivated to replace the large shot particles used in the method of Izawa et al with the small shot particles used in the claimed methods. Also, attempts to increase the kinetic energy of small shot particles by increasing the speed would not efficiently improve the fatigue property of nitrided and shot-peened springs. In other words, there would have been technical reasons why according to the prior art it would not have been desirable to reduce the diameter of the shots used in the process of Izawa et al. to arrive at the smaller shot diameter used in the claimed method.

The Examiner attempted to rely on Yamada et al. for a teaching of using smaller shots in shot peening to cure the deficiency of Izawa et al. As explained in applicants' Response to the first office action, the attempt has failed. The teachings of Yamada et al. should not be applied to modify the shot peening process of Izawa et al. because

Yamada et al. is totally silent on the role of peening steel containing nitrogen or nitrided steel with fine shot particles. Yamada et al. concentrates on carbon in steel, while Izawa et al. is related to shot peening nitrided steel springs. It appeared that the Examiner misunderstood applicants' argument because the Office Action states that applicants argued "that Yamada is directed to shot peening nitrated spring material." The fact is that applicants did not argue "that Yamada is directed to shot peening nitrated spring material" (see page 12 of the Response filed in July 2002). On the contrary, applicants argued that Yamada et al. does not teach the shot peening of steel containing nitrogen or nitrided steel.

The reason that Yamada et al does not concern shot peening of the surface of nitrided steel is explained below. Nitrided steel springs generally have a hard surface layer with the hardness highest at the surface (normally HV 800 to 1000) and gradually decreases with the depth to the core of which hardness is around HV 500 to HV 600. residual stress is obtained as a result of plastic deformation. The portion of nitrided springs at the surface (and even the portion near the surface) has been known to be very hard and not easily deformed plastically by shot peening because the very hard portion has very high yield stress. In contrast, compared with nitrided steel springs, non-nitrided steel springs have rather soft surface layers (normally HV 450 to HV 650) even after they had been shot peened. The harder the steel is, the more difficult to deform it plastically because of its high yield stress. As a result, the inventors in Yamada et al were not dealing with shot peening of nitrided steel springs especially shot peening with small shot particles, e.g. with the mean diameter less than 100 microns, since it would have been uncertain whether shot peening with small shot particles could

achieve very high compressive residual stress on the spring surface. Because Yamada et al is not related to nitrided steel springs, the teachings of Yamada et al should not have been used to modify the method of Izawa et al.

Related to Yamada et al., the Examiner also took a position that Yamada et al. was properly applied because Yamada et al. is in the field of applicants' endeavor or reasonably pertinent to the particular problem with which the applicant was concerned. Applicants respectfully disagree. There would not have been reasonable expectation that the teachings of Yamada et al. on non-nitrogen-containing steel would work on the nitrided steel spring of Izawa et al. and so Yamada et al. was not properly applied in the obviousness rejection.

Regarding applicants' argument that Izawa et al. does not teach using an impact temperature below recrystallization temperature, the Examiner argued that keeping the impact temperature below recrystallization temperature could help dislocation anchoring. The Examiner concluded that it would have been obvious to one having ordinary skill in the art of the cited references at the time the invention was made to use finer shots in a second peening stage and maintain the impact temperature below recrystallization temperature as taught by Yamada in order to improve the surface roughness and dislocation anchoring (col. 2, lines 62-67). Applicants respectfully disagree. Keeping the temperature below recrystallization temperature can possibly anchor dislocations **if dislocations are generated** during shot-peening. However, elastic deformation does not generate dislocations. Since the surface layer of nitrided springs is very hard, the person of ordinary skill in the art would have thought that it would have been rather difficult to obtain plastic deformation in the surface layer of

nitrided springs, so elastic deformation takes place predominantly. In such conditions, the person would have predicted no dislocation anchoring since dislocations are not produced. Since the person would have predicted that no dislocations are produced, the person would have no motivation to keep the temperature below recrystallization temperature.

In addition, since yield strength is not very high in the portion immediately beneath the nitrided surface (in the portion beneath the nitrided surface, the nitrogen concentration is lower than that in the surface), the person of ordinary skill in the art would have predicted that dislocations are generated and highest compressive residual stress is produced at the portion near the surface where dislocation anchoring (locking) and unlocking proceed at the same time by which dislocation multiplication is accelerated, resulting in high compressive residual stress formation. This kind of prediction appears to be different from applicants' experimental results in which the highest residual stress was obtained at the surface as is shown in Figure 3 attached.

With respect to applicants' argument related to JP '711, the Examiner stated that JP '711 was merely cited to show that different orders of nitridation were known in the art and that nitridation could be done after shot peening. However, the Examiner did not address applicants' argument that JP '711 teaches away from using the fine shot particles as in the claimed methods (see page 13 of the Response filed on July 29, 2002, which is incorporated by reference herein). The size of shot peening before surface hardening is 100 μm or more in JP '711. JP '711 does not teach the effectiveness of fine beads peening with a diameter of less than 100 μm. In fact, paragraph [0015] of J P '711 discloses that, when the diameter of shot particles to be

used for shot-peening prior to carbo-nitriding is less than 100 μm in diameter, the effectiveness of shot-peening prior to carbo-nitriding is lost. Thus, JP '711 teaches away from the claimed invention. Applicants request that the Examiner explain why applicants' "teaching away" argument was not persuasive.

The Examiner stated that applicants argued that Izawa et al. does not teach controlling the temperature rise during shot peening and using finer shot size in the second shot peening step. The Examiner took a position that applicants' argument was not persuasive because the argument was against Izawa et al. individually. Applicants respectfully disagree. Applicants' argument was not directed to Izawa et al. individually. Instead, applicants' argument was that Izawa et al. does not teach to control the temperature rise during shot peening and use finer shot size in the second shot peening, and that these deficiencies of Izawa et al. were not cured by the secondary references relied upon by the Examiner. Since these deficiencies of Izawa et al were not cured by the secondary references, the claims would not have been obvious.

The Examiner stated that applicants' arguments with respect to the obviousness rejection based on JP '216 as the primary reference were substantially the same as the arguments against the obviousness rejection based on Izawa et al. as the primary reference. As a result, applicants' reasons of traversing the obviousness rejection based on Izawa et al. as the primary reference also apply to the obviousness rejection based on JP '216 as the primary reference. Applicants request that the obviousness rejection based on either Izawa et al or JP '216 as the primary reference be withdrawn.

In JP '216, the spring surface is electro-polished before nitriding, but compressive plastic strain which causes compressive residual stress is not induced in

the spring surface layer before nitriding because its surface layer has not been mechanically deformed. In Izawa et al, residual stress or strain is removed before nitriding (Column 4, lines 4 to 9, Izawa et al). As a result, just after nitriding, the compressive residual stress is estimated to be quite low. Figure 1(a) attached to this Response is an example of residual stress distribution in such a nitrided spring of which surface scale and lubricant were removed in an acid solution before nitriding as in the prior art. In contrast, according to the present invention, especially in the method of the claim 2, high compressive residual stress is obtained at surface after nitriding because significant part of high compressive residual stress caused by fine shot particle peening prior to nitriding remains even after nitriding treatment. The attached Figure 1(b) shows the residual stress distribution in a nitrided spring which was shot-peened using fine steel beads at a speed of 135m/sec prior to the nitriding according to the method of claim 2. The method of claim 2 can obtain springs with very high compressive residual stress at the surface layer and good surface smoothness. When shot particle size is larger than that defined in claim 2, surface residual stress obtained after nitriding is smaller (as shown in the attached Figure 1(c)) and surface roughness is increased. Thus, the method of claim 2 is unexpectedly better than the prior art methods.

The differences of residual stress distribution caused by different pre-nitriding treatment in nitrided springs remain even after shot-peening following nitriding. This kind of improved surface compression residual stress caused by shot-peening with fine particles defined in the claim 2 prior to nitriding remains even after two stage shot-peening applied after gas nitriding (e.g. see the data in Table 1 below).

Table 1: Residual stress at surface after second shot peening (fine steel beads peening with a mean diameter of 37 μm, velocity 135 m/sec, and time 20 min.) following first shot peening (with 0.8 mm diameter cut steel wires, velocity 72 m/sec and time 20 min.) after nitriding carried out as described in claim 2.

Process	Treatment prior to nitriding	Residual stress at surface
Comparison	De-scaling in acid solution	- 1275MPa
Claim 2 in this invention	Fine steel beads (□43 □m) peening at 135 m/sec for 20 min.	- 1804MPa

Remark: Minus (-) in residual stress means compression.

Accordingly, with the method of claim 2, nitrided springs with far higher fatigue strength were obtainable. For example, in spring fatigue test at mean stress 686MPa and amplitude stress at +/- 677MPa, no fatigue fracture occurred until to 5 X 10^7 cycles as is shown in the attached Figure 2. This is better than the methods of Izawa et al, JP '216 or the conventional shot peening such as that described in JP '711. For example, a fatigue strength of 687MPa(mean stress) +/- 570 MPa (amplitude stress) was shown in Fig. 9 of Izawa et al.

In Izawa et al, the remaining stress or remaining deformation is removed before gas nitriding (column 4, lines 4 to 9). The surface compressive residual stress formation thus prepared and then gas-nitrided is estimated to be lower compared to the present invention. The surface roughness attained on finished spring surface according to claim 2 is minor since the surface hardness just after nitriding is increased by the fine steel beads peening prior to nitriding. Both of these are estimated to contribute to the improved fatigue strength in the spring produced by claim 2.

Conclusion

Consequently, for the reasons noted above, clear differences are present between the claimed invention and the cited prior art. These differences are more than sufficient that the present invention as claimed would not have been obvious to a person of ordinary skill in the art properly viewing the references.

With the above reasoning, applicants respectfully submit that the application is in a condition for allowance.

In the event that this paper is deemed untimely, applicants petition for an appropriate extension of time. Any fee deficiency can be charged to Deposit Account No. 01-2300, referencing Docket No. 100725-00017.

Respectfully submitted,

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Enclosures:

Marked-Up Version of Claim Amendments
Figures 1-3
Notice of Appeal and Petition for Extension of Time

168755_1.DOC

Marked Up Version of Claim Amendments

1. (Amended Twice) A spring surface treatment method, comprising the steps of:

(A) nitriding a surface layer of [springs] a spring;

(B) projecting hard metal particles having hardness which is lower than the hardness of the nitrided outermost surface layer and is in the range of Hv 500 to 800 and diameters from 200 to 900 μm against the nitrided surface of the [springs] spring at a velocity from 40 m/sec. to 90 m/sec., so as to prevent generation of a microcrack in the surface layer by the projection and provide compression residual stress comparatively deep inside the springs; and

[(c)] (C) projecting a number of fine metal particles having a mean diameter of all particles of 80 μm or less, a mean diameter of each particle in the range between l0 μm inclusive and less than 100 μm, a spherical or near spherical shape having no square portions, a specific gravity from 7.0 to 9.0, and hardness which falls in the range between Hv 600 and Hv 1100 inclusive and is equal to or less than the hardness of the outermost surface layer of the [springs] spring after nitriding or low-temperature carbonitriding at velocity from 50 to 190 m/sec., while controlling an instantaneous temperature rise limit of [the] an iron matrix excluding the nitride compound layer of the nitrided spring surface layer due to collision to be low enough to cause work hardening in the spring surface layer but not to cause softening due to recovery/recrystallization, thereby effectively work hardening and preventing generation of any microcracks in the surface layer to provide a high compression residual stress and hardness.

2. (Amended Twice) A spring surface treatment method, comprising the steps of:

(A) projecting a number of metal particles having diameters between 10 μm inclusive and less than 100 μm, a mean diameter of all particles of 80 μm or less, <u>a</u> mean diameter of each particle of 10 to 80 μm, a spherical or near spherical shape having no square portions, a specific gravity of 7.0 to 9.0, and a hardness of Hv 350 to 900 against [the] <u>a</u> surface of [springs] <u>a spring</u> before nitriding at <u>a</u> collision velocity in the range of 50 m/sec. and 160 m/sec. inclusive so that a temperature rise limit of the surface of the spring due to collision is controlled to be low enough to cause work hardening of [the] <u>an</u> iron matrix of the [springs] <u>spring</u> but lower than the point at which recovery/recrystallization may occur so as to prevent generation of any microcracks;

(B) nitriding <u>a</u> surface portion of the [springs] <u>spring</u> after [the] step (A);

(C) projecting hard metal particles having hardness which is lower than the hardness of the nitrided outermost surface layer and in the range of Hv 500 to 800, and a grain diameter of 200 to 900 μm against the nitrided surface of the [springs] <u>spring</u> at <u>a</u> velocity of 40 m/sec. to 90 m/sec., so as to prevent generation of any microcracks in the surface layer by the projection and provide compression residual stress comparatively deep inside each spring; and

(D) projecting a number of metal microparticles having a mean diameter of all particles of 80 μm or less, a mean diameter of each particle in the range between 10 μm inclusive and less than 100 μm, a spherical or near spherical shape with no square portions, a specific gravity of 7.0 to 9.0, and a hardness which falls in the range

between Hv 600 and Hv 1100 inclusive and is equal to or less than the hardness of the outermost surface layer of the spring after nitriding or low-temperature carbonitriding at the velocity of 50 to 190 m/sec., while controlling the instantaneous temperature rise limit of the iron matrix excluding nitride compound layer of the nitrided spring surface layer due to collision to be high enough to cause work hardening in the surface layer but lower than a point at which softening due to recovery/recrystallization may occur, thereby effectively causing work hardening and preventing generation of any microcracks in the surface layer to provide a high compression residual stress and hardness.

3. (Amended Twice) A surface treatment method, comprising [comprised of] the step of bombarding hard metal particles having hardness in the range between Hv 350 and 1100, specific gravity of 7.0 to 9.0, a mean diameter of all particles of 80 μm or less, a mean diameter of each particle in the range between 10 μm inclusive and less than 100 μm, and a spherical or near spherical shape with no square portions, on [the] a surface of a spring [springs] with [the] surface layer hardness of Hv 400 to 750, which hardness was obtained by one of low-temperature annealing for removal of macroscopic residual stress after cold forming, quenching and tempering after cold forming, and quenching and tempering after hot forming, at [the] a collision velocity of 50 m/sec to 160 m/sec, while controlling the temperature rise limit of the spring surface layer due to collision to be low enough to cause work hardening in the spring surface layer but not to cause softening due to recovery/recrystallization and preventing generation of any microcracks in the surface layer which may deteriorate fatigue

strength, thereby improving the hardness and compression residual stress of the surface layer which is 30 μm to 50 μm or less deep from the surface and resulting in improved endurance of the <u>spring</u> [springs].

4. (Amended Twice) A spring surface treatment method for preventing generation of harmful microcracks in <u>a</u> surface layer <u>of a spring</u> which may deteriorate fatigue strength and for improving especially the hardness and compression residual stress of the surface layer which is 30 μm to 50 μm or less deep from the surface, to improve endurance of the <u>spring</u> [springs], the method comprising the steps of:

(A) projecting hard metal particles having hardness of Hv 350 to 900 and [the] <u>a</u> particle diameter of 200 to 900 μm against the surface of <u>a</u> formed and tempered <u>spring</u> [springs] having [hardness of the] <u>a</u> surface layer <u>with hardness</u> of Hv 400 to 750 at [the] <u>a</u> velocity of 40 m/sec to 90 m/sec so as to prevent generation of harmful microcracks in the surface layer and provide compression residual stress comparatively deep inside the <u>spring</u> [springs]; and

(B) performing the surface treatment method according to claim 3 on the spring surface after [the] step (A).

5. (Amended Twice) A spring surface treatment method according to claim I or 2, wherein the particles <u>projected in step (C) of claim 1 or step (A) of claim 2</u> [having a mean diameter of all particles of 80 μm or less and a mean diameter of each particle in the range between 10 μm inclusive and less than 100 μm] and the projection conditions of the particles are limited to the following:

hardness of projected particles: initial hardness being Hv 600 to 1100;

size of projected particles: initial mean diameter of each particle being 10 μm to 80 μm;

mean diameter of all particles: 65 μm or less;

specific gravity of projected particles : 7.0 to 9.0; and

collision velocity against the spring: 60 m/sec. to 140 m/sec.

6. (Amended Twice) A spring surface treatment method according to claim 3 or 4, wherein the particles used to bombard the spring surface [having a mean diameter of all particles of 80 μm or less and a mean diameter of each particle in the range between 10 μm inclusive and less than 100 μm] and the projection conditions of the particles are limited to the following:

hardness of projected particles: initial hardness being Hv 350 to 1100;

size of projected particles: initial mean diameter of each particle being 10 μm to 80 μm;

mean diameter of all particles: 65 μm or less;

specific gravity of projected particles: 7.0 to 9.0; and

collision velocity against spring: 60 m/sec. to 140 m/sec.

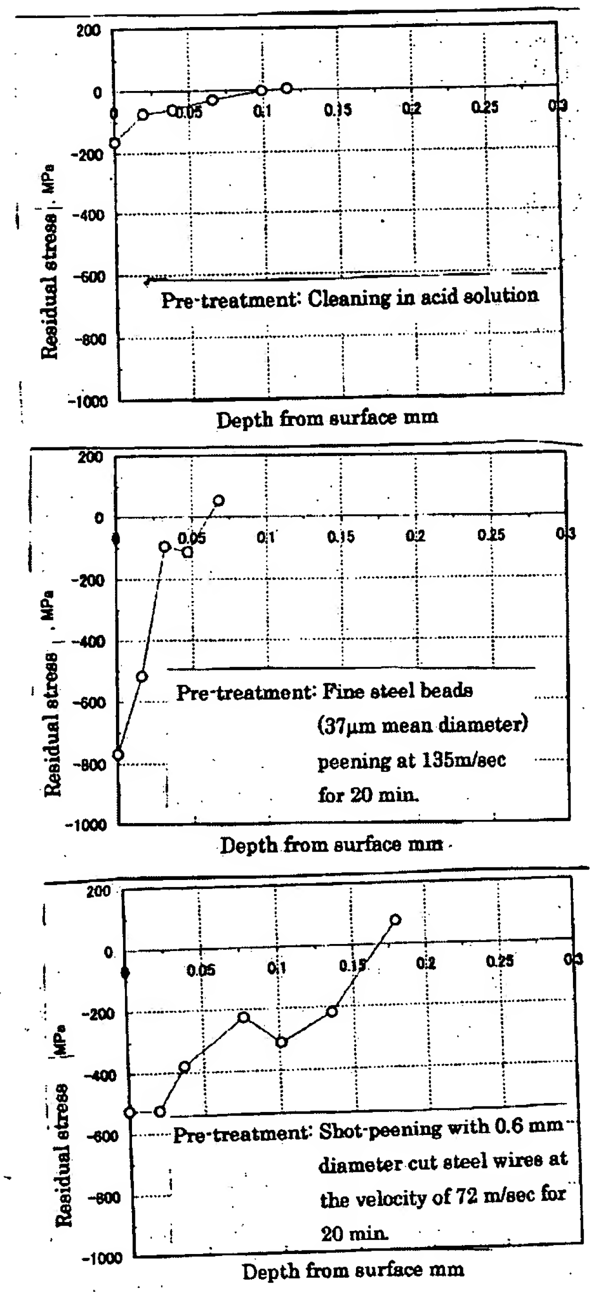

Figure 1(a)

Figure 1(b)

Figure 1(c)

Figure 1. Effect of pre-treatment prior to gas-nitriding on residual stress distribution of as-nitrided steel spring. Wire: High strength oil-tempered wire with a diameter of 3.2mm Nitriding: 435degree C for 3 hrs

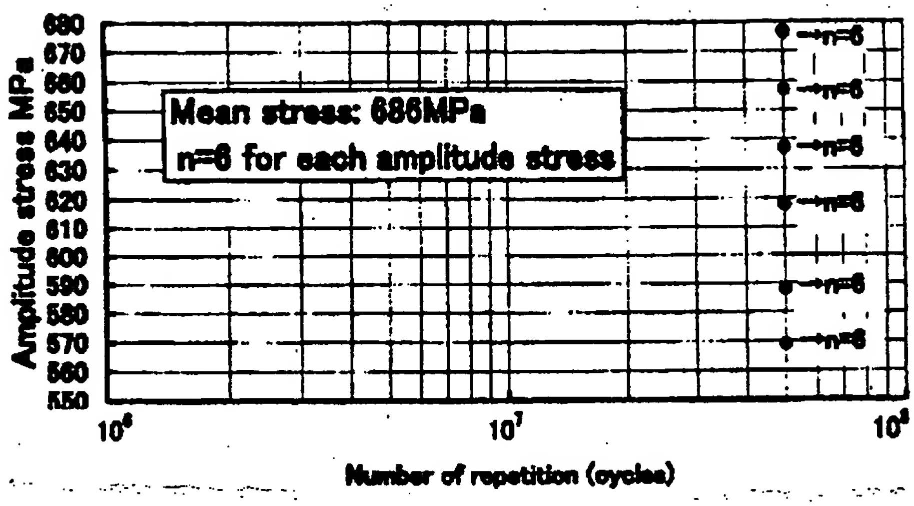

Figure 2. Fatigue test results on nitrided springs produced in the processes according to the claim 2 in the patent application by Ishida et al, Suncall. The arrows (→) in the figure indicate no fatigue fracture and n means specimen numbers fatigue tested.

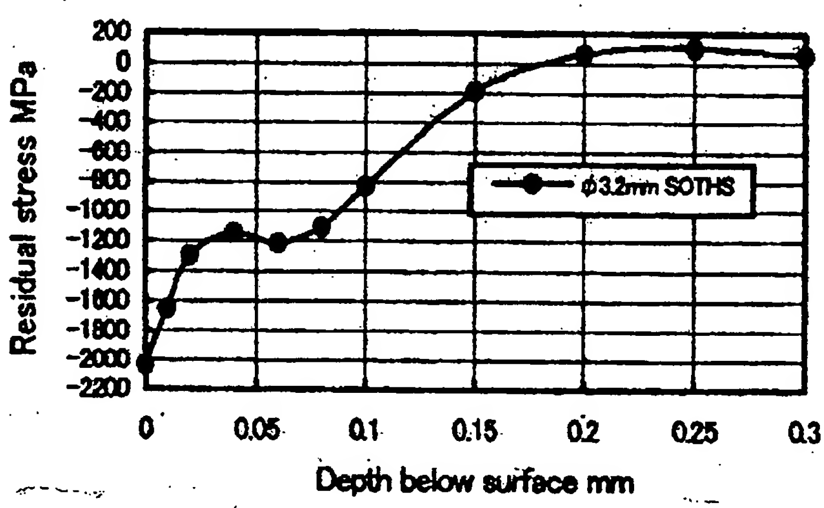

Figure 3. Residual stress distribution in the surface of a nitrided spring produced according to the processes in the claim 2 in the applied patent by Ishida et al of Suncall Corp.